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THESIS

**COMPARISON OF "FUNCTIONAL CONCEPT OF
BATTLESPACE AWARENESS" VERSUS THE CONCEPT OF
"POWER TO THE EDGE," WITH A FOCUS ON
INTEGRATING SHOTSPOTTER SENSORS AND UNMANNED
AERIAL VEHICLES**

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September 2005

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ABSTRACT

Current military doctrine is primarily hierarchical in nature with respect to power and authority. The "Functional Concept of Battlespace Awareness" (FCBA) is a military sensor methodology that employs a hierarchical command structure to test emerging technologies. Asymmetric warfare, however, demands a faster and more adaptive warfighting mentality that distributes power and responsibility across more of our forces; particularly those that are at the frontlines of the battlefield. "Power to the Edge" is a warfighting concept that emphasizes a departure from traditional military hierarchies and a transition into a configuration that empowers "Edge" actors with information and authority. The exploitation of tactical opportunities by edge actors is essential to victory for an edge organization, and fundamentally what makes it more effective than traditional hierarchies. This thesis will explore the concept that "Power to the Edge" doctrine is a more effective way to fight the enemies we will likely face in the Information Age. By analyzing and interpreting data collected at the Extended Awareness II and Extended Awareness IIB experiments, this thesis intends to explore an example of transition in our current command and control methodology to keep up with a changing enemy.

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I. METHODOLOGIES

A. THESIS INTRODUCTION AND PURPOSE

The Information Age is certainly changing the ways in which our military will fight the battles of the future. What is not certain is the command and control doctrine best-suited for the U.S. military of the future. This thesis will compare and contrast two different methodologies for command and control: 1) Functional Concept for Battlespace Awareness (FCBA) 2) *Power to the Edge*. To do this, this thesis will use data collected at a series of experiments entitled Extended Awareness (EA). EA investigates how new advances in tactical sensor technologies, fusion systems, and display systems will change our military's battlefield situational awareness. EA experimentation is done within the framework of FCBA command and control concepts.

To further examine the ideas set forth in both FCBA and *Power to the Edge*, this thesis will use data and observations from EA. Specifically, data collected from an acoustic gunshot location sensor called Shotspotter will be used to explore the potential effectiveness of FCBA and *Power to the Edge*. To examine FCBA and *Power to the Edge* using Shotspotter as an example, this thesis is organized as follows:

- Background information on FCBA and *Power to the Edge*
- An overview on what Shotspotter is and how it works

- Summary of the fundamentals of the Extended Awareness experiments and data collected there
- Analysis of how Shotspotter sensors might fit into future Command and Control scenarios

This thesis intends to show ways that concepts, derived from *Power to the Edge*, can potentially be used to create a more agile Information Age force.

B. FUNCTIONAL CONCEPT FOR BATTLESPACE AWARENESS (FCBA)

1. Background

The Functional Concept for Battlespace Awareness (FCBA) was developed by the Joint Chiefs of Staff as part of a capabilities-based analytical construct that supports the Joint Capabilities Integration and Development System (JCIDS) and Joint Requirements Oversight Council (JROC) decision-making.¹ In addition, FCBA is designed to be a tool to generate new ideas regarding command and control concepts and architectures. FCBA was released on December 31st, 2003.

Most pertinent to this thesis, FCBA is used as model for conducting military experiments and exercises- such as the Extended Awareness (EA) series of experiments. FCBA is designed to be a forward looking document, focused on military operations in or around 2015. FCBA assumes that there will be tremendous amounts of sensor and information capabilities available in the future, and seeks to develop best practices for employing those capabilities.

2. FCBA Key Concepts

FCBA focuses on ensuring that key decision-makers are well informed about the condition of the battlespace.

¹ Joint Chiefs of Staff, *Functional Concept of Battlespace Awareness* (Washington, D.C.: DoD, 2003), 10.

Ideally under FCBA, these decision-makers will be more capable of "making better decisions faster by enabling a more thorough understanding of the environment in which they operate, relevant friendly force data, the adversaries they face, and non-aligned actors that could aid in or detract from friendly force battlespace success."² The key to this enhanced decision-making ability is the presence and access to a ubiquitous network that promotes information sharing at all levels.

Decision-makers are at the core of all important decisions and are empowered by both *information* and *authority*. FCBA caters to the information needs of higher level decision-makers without strongly focusing on those of lower level tactical decision-makers. This is because FCBA is designed for operations where only higher echelon commanders have the authority to make decisions. While FCBA advocates the availability of sensor data at all levels, the primary focus is for information to flow upwards from tactical actors to support higher level commanders vested with the authority. Regarding the interface with decision-makers, FCBA states the following:

The BA Functional Concept begins and ends with the decision maker. The value of BA is ultimately measured by its ability to interact with and provide decision makers with the information required for quality, timely decisions. The decision maker uses tailor-able operational pictures to visualize the battlespace.³

Thus, decisions will continue to come from above as it does in traditional hierarchical organizations. The forward looking nature of this document is that these decisions

² *Functional Concept of Battlespace Awareness*, 2.

³ *Functional Concept for Battlespace Awareness*, 4.

will be bettered by new technology, leading to increased battlespace awareness.

FCBA envisions that information will be available across the spectrum of strategic and tactical actors, but that empowerment, that is authority to act upon that information, will still reside within the same levels of our current military. This is not to say that tactical decision-makers have no authority to make decision, but that many of their actions will still be dictated by higher level decision makers.

FCBA says information will flow faster and will, in theory, speed up the decision making cycle of those commanding tactical forces. Figure(1) below shows how FCBA intends to get the right information, to the right personnel, at the right time.

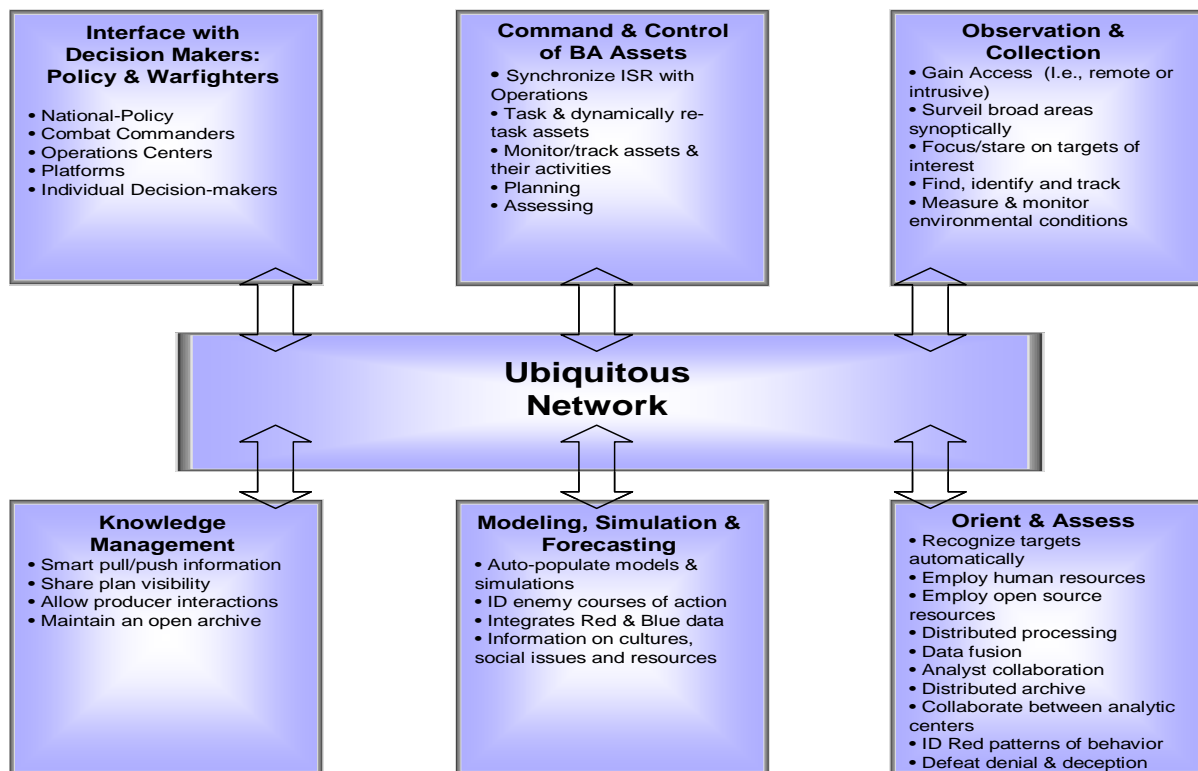


Figure 1. The Joint BA functional Concept (From: FCBA)

C. POWER TO THE EDGE

1. Background

Power to the Edge (a Command and Control Research Program (CCRP) publication (2003))⁴ focuses on military operations centered at or around 2050. CCRP is a DoD organization under the Assistant Secretary of Defense, Networks and Information Integration (ASD(NII)).

CCRP is charged with: 1) improving both the state of the art and the state of the practice of command and control and 2) enhancing DoD's understanding of the national security implications of the Information Age.⁵

Power to the Edge was written at the request of John Stenbit, the ASD(NII) who wanted to develop a broader understanding of the principles being used to develop policy, make decisions regarding investments in C4ISR, and provide oversight of ongoing DoD programs and related activities that will provide the ubiquitous, secure, wideband network that people will trust and use, populate with high quality of information, and use for developing shared awareness, collaborating effectively, and synchronizing their actions.⁶

2. Power to the Edge Key Concepts

Power to the Edge was written as a transformational guide, creating a more agile force by using principles of Network Centric Warfare (NCW) to empower the "edge" users. *Power to the Edge* advocates empowering the "edge" of military organizations, defined as the point at which the organization interacts with its operating environment. *Power to the Edge* empowers the "edge" with information and authority to act in line with the commander's intent, but

⁴ David S. Alberts and Richard E. Hayes, *Power to the Edge* (Washington D.C.: CCRP, 2003), xiii.

⁵ Command and Control Research Publications Homepage http://www.dodccrp.org/html2/about_program.html 16 August 2005

⁶ Alberts and Hayes, xx.

not necessarily under the commander's direct control. Empowering the "edge" creates a more direct line of communication between the edge actors and key decision-makers.

Traditional hierarchies share information vertically up then back down the organization. Through the use of ubiquitous information sharing, *Power to the Edge* will eliminate much of the middle management that currently slows the decision-making cycle. Sharing near real-time intelligence across the battlefield allows key decision-makers to virtually be on the "edge" along with the literal tactical "edge" actors. In addition, *Power to the Edge* concepts greatly increase peer-to-peer interactions as required by the mission at hand.

Power to the Edge proposes robust information sharing through the use of a single ubiquitous network. This hypothetical ubiquitous network would link all relevant people, data bases, and systems in a matter unrestrained by bandwidth or computing power. When fully applied to systems architectures, the result will be an edge infostructure that has the characteristics of DoD's future Global Information Grid (GIG).⁷ The GIG (shown in Figure (2)) is a concept that will notionally combine massive databases, intelligence analysts, huge amounts of sensor data, and complete information sharing in order to bridge the gap between strategic and tactical decision-makers. Overall, the GIG enables full information sharing across the entire spectrum of relevant forces- the ultimate goal of an edge organization.

⁷ Alberts and Hayes, 180.

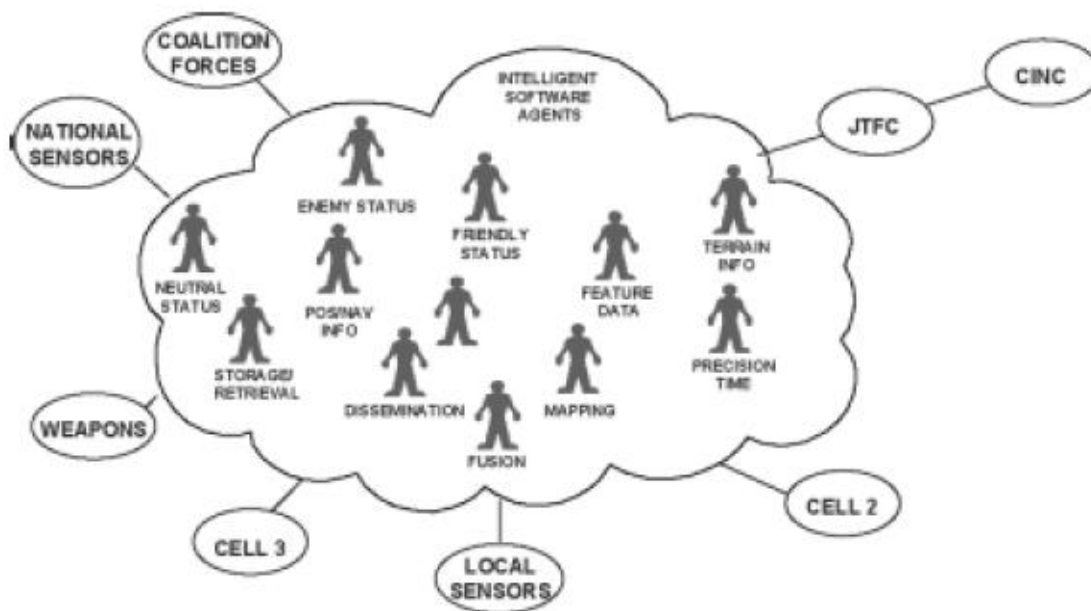


Figure 2. GIG Model (From: *Power to the Edge*, 183)

Figure (2) shows a conceptual model of how information sharing might take place in the future. At the center, all personnel involved have access to the same information across the spectrum of data collection methods, from various coalition forces to national sensors. Ideally, this will allow all connected on the grid to share not only information, but understanding of that information.

Enabling *Power to the Edge* is not an easy task and requires an almost complete restructuring of current military command and control conventions. Rather than making the majority of key decisions, commanders will be responsible for creating the conditions to successfully enable the edge without sacrificing military wisdom that comes from experience. Under *Power to the Edge*, commanders will find themselves in a position to exercise command more in the planning stages of operations than in the operational stages of the battle. This will allow their

empowered edge actors more freedom of action during combat because edge actors will not, necessarily, be bound by direct orders from commanders. Although this may seem to relinquish commanders from controlling their forces, commanders will still maintain control by:

- Creating congruent command intent across the enterprise;
- Allocating resources dynamically; and
- Establishing rules of engagement and other mechanisms that the fighting forces implement themselves.⁸

Power to the Edge concepts empower tactical "edge" actors with the knowledge and authority previously reserved for higher echelon commanders. Empowering the "edge" requires a drastic change in current military culture, training and doctrine, but offers far greater agility in exchange.

D. CONTRASTING METHODOLOGIES

1. Similarities

The similarities between FCBA and *Power to the Edge* are abundant, and the enabling fundamentals of both methodologies are worth mentioning. Both recognize that the key to an effective fighting force is Network Centric Warfare and Operations (NCW/NCO). FCBA and *Power to the Edge* both rely upon a ubiquitous network to provide information sharing throughout friendly and coalition forces. The information to enable NCW/NCO in both concepts relies upon massive amounts of sensors that feed tactical

⁸ Alberts and Hayes, 5.

and higher level commanders. Stovepipe architectures are eschewed by both methodologies in preference for a far more connected and adaptable architecture.

2. Differences

The similarities between the FCBA and *Power to the Edge* concepts are many, but it is the differences that shed light on potential advantages of an edge-organized military. The truly new concept of *Power to the Edge* is the empowerment of "edge" actors. While both FCBA and *Power to the Edge* stress the importance of information sharing through a ubiquitous network, only the *Power to the Edge* concept advocates a shift towards empowering the people at the tip of the spear with authority. *Power to the Edge* empowers edge actors with authority to act upon their increased battlespace awareness in accordance with the promulgated commander's intent. It is this key concept that defines *Power to the Edge* battlespace awareness. *Power to the Edge* puts forth the idea that greater situational awareness at lower levels warrants increased authority to act at those lower echelons. It follows that Edge actors will, in theory, have an extremely high level of agility since they are empowered with the authority and situational awareness to act against emerging threats. This desired agility is an important distinction because it demands a fundamental evolution in military organization.

FCBA uses a traditional military hierarchy (chain of command) to exercise command, and only uses a mesh topology (defined in Figure (3)) to link all echelons for information flow only.

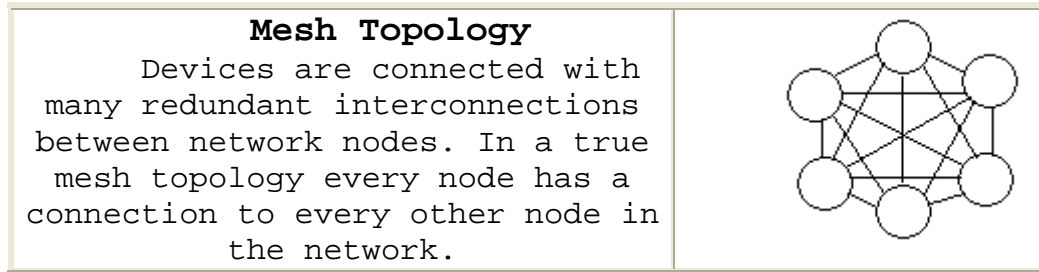


Figure 3. Mesh Topology (From: http://www.webopedia.com/quick_ref/topologies.asp)

Power to the Edge relies on much more adaptable and agile organization, with both information and authority residing in those edge actors involved in a mission. Table (1) shows a comprehensive breakdown between edge organizations and traditional hierarchical organizations, clearly demonstrating the fundamental differences between the two.

| | Hierarchies | Edge Organizations |
|-------------------------------|---|---|
| Command | By directive | Establishing conditions |
| Leadership | By Position | By Competence |
| Control | By direction | An emergent property |
| Decision-making | Line function | Everyone's job |
| Information | Hoarded | Shared |
| Predominant Information Flows | Vertical, coupled with chain of command | Horizontal, independent of chain of command |
| Information Management | Push | Post – Pull |
| Sources of Information | Stovepipe monopolies | Eclectic, adaptable marketplaces |

| | | |
|--------------------------|-----------------------|--------------------|
| Organizational Processes | Prescribed Sequential | Dynamic Concurrent |
| Individuals at the Edge | Constrained | Empowered |

Table 1. Comparison of Attributes of Hierarchies and Edge Organizations. (From: *Power to the Edge*, 218)

3. Innovative nature of *Power to the Edge*

Power to the Edge is an innovative concept because it promotes a drastic departure from conventional military organization. It recognizes that the Information Age has dramatically altered the face of war. This is because newer and more versatile information networks are appearing, making strict hierarchies less agile in comparison. The USAF Scientific Advisory Board recognized in 1995 that "new networks emerging today are 'geodesic,' that is global, non-hierarchical and without any central node." They predicted that "it is a safe bet that our [military] organizations will follow suit."⁹ *Power to the Edge* provides the fundamentals which our forces can use to transform themselves into a more agile organization. This will theoretically develop a network-centric force capable of countering equally agile Information Age threats. This force will rely upon NCW fundamentals such as:

- A robustly networked force improves information sharing
- Information sharing enhances the quality of information and shared situational awareness
- Shared situational awareness enables collaboration and self-synchronization, and enhances sustainability and speed of command.

⁹ Gregory A. Roman, "The Command or Control Dilemma: When Technology and Organizational Orientation Collide." *Maxwell Papers*, no. 8 (1997): 2.

- These, in turn, dramatically increase mission effectiveness.¹⁰

This agility, the capability to fight the emerging "geodesic" threats in Information Age warfare, requires a change in the empowerment of edge personnel in military operations. *Power to the Edge* reduces the importance of the chain of command with regards to decision-making during combat operations. *Power to the Edge* lays the onus on commanders to develop the initial conditions that will put their lower level "edge actors" in the best position to succeed in the battlespace. This is necessary as the faster tempo of Information Age warfare negates the ability of commanders to work within a decision cycle that works within combat operations time-scales. This is an emerging characteristic of modern warfare.

During Operation DESERT STORM, considered to be the first "Information Age war" by many, the speed of events limited General Schwarzkopf's command and control ability.¹¹ Specifically it was "the unexpected rapidity with which the Marines advanced on the right accelerated events beyond Schwarzkopf's ability to precisely control them."¹² It was his clear commander's intent that allowed his subordinates to act without his direct control. So detailed and well understood was his commander's intent that with the exception of one decision regarding timing, "Schwarzkopf could have left the theater to his subordinates to carry

¹⁰ DoD Office of Force Transformation, *The Implementation of Network-Centric Warfare* (Washington, D.C.: DoD, 2005), 7.

¹¹ David J. Lonsdale, *The Nature of War in the Information Age* (New York: Cass, 2004), 70.

¹² Carl H. Builder and Steven C. Bankes and Richard Nordin, *Command Concepts: A Theory Derived from the Practice of Command and Control* (Washington, D.C.: RAND, 1999), 70.

out his plans."¹³ As the Information Age progresses and the tempo of war increases, this style of decentralized leadership will be necessary at lower and lower levels. *Power to the Edge* advocates this shift to a higher degree of autonomy at lower levels.

This autonomy at lower levels is not a new concept either. Van Creveld states that, "historically speaking, those armies that have been most successful ... did not turn their troops into automatons, did not attempt to control everything from the top, and allowed subordinate commanders considerable latitude."¹⁴ *Power to the Edge* is innovative because it points out that Information Age technology enables and requires this concept to be applied to even lower echelon actors. By doing so, *Power to the Edge* moves towards the merging of the planning and execution processes "into a seamless form of command and control," as is envisioned in *Network Centric Warfare*.¹⁵

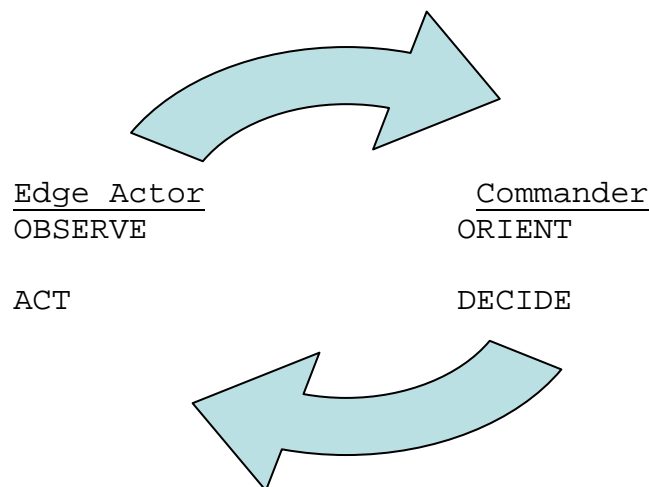


Figure 4. Traditional Edge Actor, Commander OODA Loop

¹³ Ibid, 69.

¹⁴ Van Creveld, 270.

¹⁵ David S. Alberts and John J. Garstka and Frederick P. Stein, *Network Centric Warfare* (Washington, D.C.: CCRP, 1999), 74.

In terms of the traditional OODA (Observe, Orient, Decide, Act) loop decision model, commanders empower their edge units to complete the OODA loop at their lower level by giving them the initial tools to make the right decisions— tools like equipment, intelligence, techniques, tactics, procedures, and rules. Traditionally, the role of the commander is to take the edge actor's observations and other intermediate commander's information, orient them, and then decide upon a course of action (Figure 4). In the Information Age, this is too slow because, at the very least, two full OODA loops cycles must be completed. A thorough commander's intent and superb situational awareness allows the edge actors to orient themselves within their environment without having to wait for orientation by superiors. Commanders can still rest assured that their subordinate's orientation is in line with their vision because the edge actors have already been informed, via the commander's intent, as to their role in the operation.

Admiral Lord Nelson's naval battle at Trafalgar provides an excellent example of a successful implementation of commander's intent. In 1805 Nelson's flagship, the HMS Victory, hosted a meeting between the captains of Nelson's fleet. Knowing that communications would be impossible after the onset of battle, Nelson described a bold plan to defeat the French and Spanish fleets. Nelson knew that the French and Spanish ships had superior firepower and size. Nelson also knew that his ships were more maneuverable and manned by superior crews. Keeping these strengths and weaknesses in mind, Nelson devised a plan to attack the French and Spanish ships from

the side, a daring plan that would put his fleet in direct aim of French and Spanish broadside cannons. Trusting the competence of his fleet's captains, Nelson attacked the French and Spanish ships with devastating effectiveness, sinking 20 French and Spanish ships with no loss of British ships.¹⁶ Nelson's ships broke through the French and Spanish ship's lines and delivered annihilating cannon fire to the bows and sterns of the his enemy's ships— inherently vulnerable places since the cannon shot could travel the full length of the ships.

Nelson's plan worked masterfully although, ironically, Nelson was killed in the battle. The beauty of Nelson's plan was not his skilled naval tactics, but in his empowerment of his ship's captains. The crux behind the British victory was their ability to self-synchronize, an idea that will be explored in greater detail later in this thesis. Essentially, all of Nelson's ships acted independently with only one bit of guidance: Nelson's commander's intent. After their meeting, Nelson's captains had no means to communicate with one another, a potentially crippling vice had Nelson not established his intent prior to the engagement. Nelson's actions epitomize using commander's intent to empower edge actors.

Having observed and oriented themselves, edge actors can then decide upon a course of action that will best move towards the commander's expected end-state. What enables edge actors to make these decisions at the lower level are well thought-out set of rules of engagement. These rules of engagement are a form of guidance as to what decisions are acceptable to the commander. Thus the combination of

¹⁶ Alberts and Hayes, 31.

commander's intent and rules of engagement allow the entire decision cycle to be at the edge actor's level, reducing latency in the cycle. This creates a much more agile, and battlefield adaptable, force.

Clearly, commander's intent is not a new idea. As shown earlier, Lord Nelson used commander's intent to decisively beat the French and Spanish. Nevertheless, Lord Nelson used commander's intent out of necessity since his forces could not communicate. How, then, will commander's intent be different in the Information Age?

While operating within commander's intent is not a totally new concept within warfare (Caforio, 2003; Pratten, 1996), the extent and ubiquity of it within the NCW [Network-Centric Warfare] context is new. What's more, it is probably one of the most problematical of all NCW concepts to deal with, as it requires a paradigm shift in tradition and culture, for both senior officers and junior commanders. It requires development of the locus of decision-making, independence, empowerment and confidence in the decision-makers, and the requisite intelligence and skills for continual self-synchronization.¹⁷

Empowering the edge-warfighters while on the battlefield is a difficult command and control concept to institute because it entails a dramatic change in commanders' roles. Rather than being responsible for the hard decisions based on incomplete information, they are tasked with the creation of clear and *empowering* commander's intent and rules of engagement. Following the creation of these two vital pieces of information for their edge actors, a commanders' main role is to monitor the operation and apply changes as necessary to ensure success.

¹⁷ Australian DoD Defense Science and Technology Organization, *The Network Centric Warrior: The Human Dimension of Network Centric Warfare* (Salisbury, Australia: DSTO, 2004), 17.

4. Commander's Intent

A concise expression of the purpose of the campaign or operation, the desired results and how operations will progress towards achieving the desired end-state. At the tactical level, the commander's intent should be focused on the effect that he wishes to achieve on the enemy.

-Joint Warfare Publication 0-01.1

The commander's intent is a major enabler of an "edge organization." As previously discussed, commander's intent allows edge actors to perform the orient function of the decision cycle on their own. The Marine Corps certainly views the commander's intent as an empowering concept. Marine Corps Doctrinal Publication 6 points out that a subordinate's (an edge actor) firm understanding of the commander's intent "allows us to exercise initiative in harmony with the commander's desires."¹⁸ *Power to the Edge* takes is one step further in the creation of an agile force. The commander's intent will give them the ability to freely exercise initiative. Again, the concept of a commander's intent, and its importance, is not a new idea. What is new from *Power to the Edge* is that commander's intent will be necessary at much lower levels in the military. As a result, edge actors will be given tasks and intents that they are sufficiently trained and equipped to accomplish.

5. Rules of Engagement (ROE)

Crafting thorough ROE is another vital role of a commander in creating initial conditions conducive to success on the battlefield. The vast importance that ROE will play in future operations is a unique trait of *Power*

¹⁸ United States Marine Corps, *Marine Corps Doctrinal Publication 6,1 Command and Control* (1996)
http://www.tpub.com/content/usmc/mpdpup6/css/mpdpub6_120.htm

to the Edge. Current rules of engagement are set forth in a manner that is not consistent with the vision of the *Power to the Edge* concept because, by definition, ROE limit the actions of our forces.

While there is no clear way to predict the manner by which Information Age ROE will be written, it is clear that the "challenge is to get the ROE close to right *before* operations start and thereafter adapt them quickly and effectively as necessary."¹⁹ It can be reasonably argued that more liberal ROE may be a facet of edge military organizations. Edge actors must be empowered with the authority to act, and not unduly restrained by ROE that prevent them from either self defense or mission accomplishment. Many would argue that greater freedom within lower echelons regarding ROE will cause poor decision-making by inexperienced edge actors. *Power to the Edge* recognizes that inexperience is a shortcoming in current military doctrine, and insists that maintaining a high level of competence at the edge is crucial.

6. Self-Synchronization

Self-synchronization is the NCW tenet that proposes that an organization can function on its own given the proper conditions:

- Clear and consistent understanding of command intent;
- High quality information and shared situational awareness;
- Competence at all levels of the force; and

¹⁹ Russell W. Glenn and Gina Kingston, *Urban Battle Command in the 21st Century* (Arlington: RAND Corporation, 2005), 51.

- Trust in the information, subordinates, superiors, peers and equipment.²⁰

An important distinction to note here is that self-synchronization cannot work without command; rather, self-synchronization requires an expert level of command to meet the aforementioned conditions. Ensuring clear and consistent understanding of command intent will be the most difficult self-synchronization task for the commander to achieve. *Power to the Edge* relies less on a directed method of leadership and more on a focus of effort on the core objectives of each mission. It definitely does not lessen the importance or the skill required of a commander. The transformation is that a commander's most important role becomes to impart a clear and consistent understanding of intent to the command. In order to do so, the commander will have to be more specific in stating intentions, while maintaining clarity of vision throughout the mission planning.

High quality of information and shared situational awareness may be the easiest self-synchronization tenet to attain for a number of reasons. Sensor capabilities and actionable military intelligence should be better in the future due to the fast pace of current technological progression. Technological advances dictate that as the amount and quality of information increase, our ability to share that information will increase as well. The push to increase shared situational awareness is not a new goal for any military. In the future, however, our ability to collect, process, and disseminate information will only be limited by our imaginations. Nevertheless, the ability to

²⁰ Alberts and Hayes, 27.

make good decisions based on that information will always be an inescapable challenge facing military commanders.

Since our military has always sought better information, progressing towards getting better information will be a natural step for our forces, and not necessarily a transformational concept. "The history of command in war consists essentially of an endless quest for certainty."²¹ The key to transformation into an edge organization is the proper application of the increased information and situational awareness. New technologies must be utilized in an edge organizational structure, not as simply new aids to current hierarchical structures. Thus the challenge is to take this natural progression in information and situational awareness improvement and apply it towards the goal of creating an edge organization.

Achieving competence at all levels of our forces has always been a continuing goal of the military. The services want quality people in uniform to do a good job. In the Information Age, "what will change, though, is the definition of quality."²² Quality individuals will be ones who are able to deal with the authority that increased empowerment will place upon them. The keys to creating a force capable of accepting this burden of authority will be training and organization. First the military must transform itself into an edge organization. Only then can we begin to train our edge forces to be more capable. By training our forces to act via commander's intent rather than direct orders, we will develop empowered edge actors.

²¹ Martin Van Creveld, *Command in War* (Cambridge: Harvard University Press, 1985), 264.

²² Steven Mets, *Armed Conflict in the 21st Century* (Carlisle Barracks: SSI, 2000), 74.

In addition, we will need to train edge forces that are prepared for the authority of more flexible ROE. Furthermore, we will need to retain experienced edge actors at the edge. These experienced edge actors will be capable of the tasks put before them, accustomed to their empowerment on the battlefield, and well aware of the different friendly capabilities to which they can dynamically network during combat. This will create a more professional, more capable and agile military force.

Developing trust in information, subordinates, superiors, peers and equipment will also be tremendously challenging considering the drastic changes that are inherent in a shift to an edge organization. Trust can generally be seen as the "willingness of one person or group to relate to another in the belief that the other's actions will be beneficial rather than detrimental, even though this cannot be guaranteed."²³ This is an integral part of the empowerment of edge actors. Although commanders will still be responsible for their organization's actions, they must delegate their authority to the edge actors. This requires trust between both parties, trust that can only be developed through extensive training. Moreover, edge actors and commanders must grow to trust the sensors and networks that will provide them with their battlespace awareness.

One of the concerns of enhanced battlespace awareness is that as commanders find themselves more informed about the battlespace, they may tend to move towards centralized control. It is only through training and trust in their subordinates that will prevent these commanders from

²³ John Child, *Organization: Contemporary Principles and Practice* (Malden, MA: Blackwell, 2005), 339.

slowing down the edge organization through direct control. Quite simply put, "the seductiveness of information technology stimulates military organizational structure towards greater centralized control and more rigid hierarchical organizations instead of the desire orientation of decentralized control and more flexible organizations."²⁴ This is such a great concern that FCBA specifically listed this as a risk of the increased battlespace awareness. FCBA states:

Military personnel at the tactical level have less time to interface with BA [Battlespace Awareness] systems and nodes than those conducting operations from remote command posts. Consequently, with their superior view of the overall battle situation, upper echelon commanders could be prone to exercising more centralized control over subordinates, potentially reducing their flexibility and effectiveness to rapidly exploit tactical opportunities in the battlespace.²⁵

This idea of technology enabling centralized control is the antithesis of *Power to the Edge* concepts. The exploitation of tactical opportunities by edge actors is the key to victory for an edge organization, and the fundamental theory that differentiates it from traditionally organized hierarchies. Again, this is only possible through a great deal of trust throughout the organization as a whole. Regarding trust between the elements of a force, *Power to the Edge* states, "They [Superiors-Subordinates] will also have to trust one

²⁴ Roman, 3.

²⁵ *Functional Concept for Battlespace Awareness*, 13.

another, recognizing value of synergistic efforts and their ability to rely on one another to achieve them."²⁶

²⁶ Alberts and Hayes, 158.

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II. SHOTSPOTTER

A. SHOTSPOTTER BACKGROUND

Shotspotter is an acoustic gunshot detection device that was developed and patented in the early 1990's. The idea of acoustic detection arose from the use of acoustic sensors to locate earthquakes. Many of the triangulation principles used to locate earthquakes were then applied to locating gunfire. After years of research and development, Shotspotter sensors were used to detect gunfire in Redwood City, California. Results exceeded expectations and Redwood City's crimes related to gunfire dropped markedly. The sensors have since been moved to many urban environments where gun related crimes plague the streets.

The success of Shotspotter in an urban environment pointed to the possibility of using the same technology in an urban warfare or low-intensity conflict battlespace, leading to extensive development and testing of the Shotspotter system for military applications. Shotspotter was tested during the series of Extended Awareness experiments in simulated military situations such as convoys, patrols, and installation defense.

B. SHOTSPOTTER TECHNOLOGY

When a gun is fired the exploding propellant creates a distinct acoustic signature from the muzzle blast. Shotspotter works by utilizing an array of directional acoustic sensors in conjunction with GPS location. Once the sensor detects a firing event, it relays its own position and the direction of the gunshot to a central base station. In the Extended Awareness II experiments, the sensors

communicated through a dedicated 900 MHz line of sight radio link. The base station then compiles the reports of the sensors and deduces the type of weapon, range of the gunshot from each sensor, and the direction of the gunshot from each sensor. Utilizing the GPS location on each sensor, the base station is capable of producing accurate coordinates of the gunfire's origin. Shown below, figure (5) demonstrates how Shotspotter works at the most basic level.

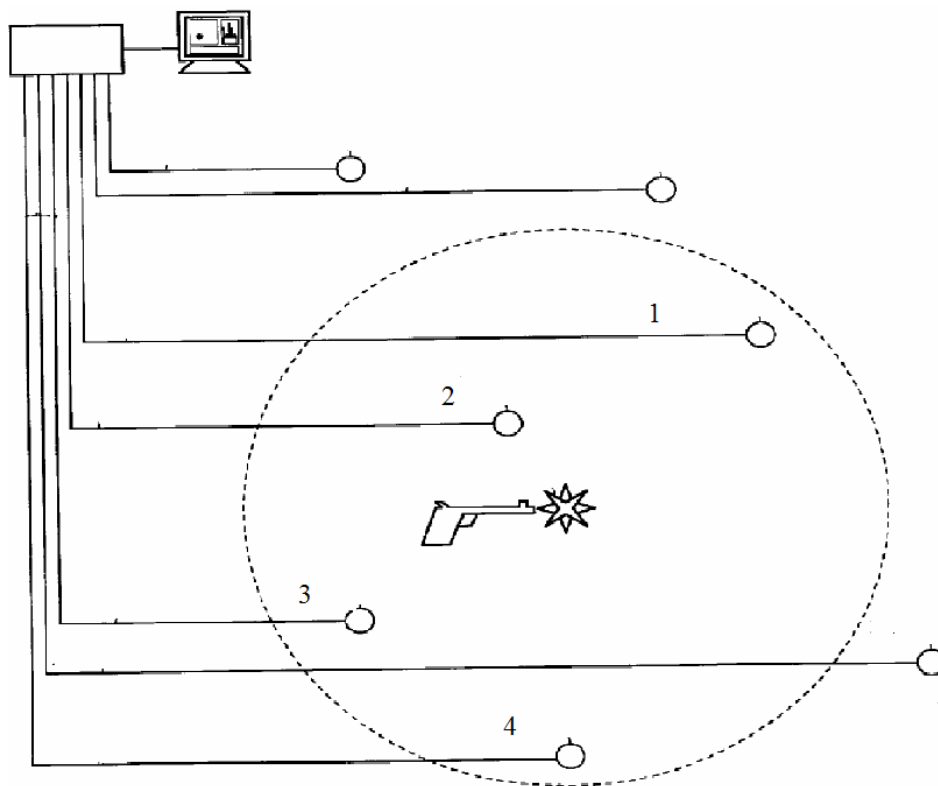


Figure 5. Shotspotter Gunshot Detection Array (From: Shotspotter Patent, U.S. Patent #5,973,998)

The technology behind the sensors relies upon the uniqueness of a gun shot's acoustic signature. The decibel ranges (140-160 dB) of a gunshot are not common in the urban environments in which US forces are likely to deploy

in the future. This is due to the strength and abruptness of the acoustic signature associated with firearms. Only fireworks and automobile back-fires are of similar strength and abruptness, but are easily filtered by the base station. The groundbreaking nature of Shotspotter is the unique "Spatial Filtering" ability of the individual sensors. This software function distinguishes gunfire from any other sound. The specifics of Spatial Filtering are a closely guarded Shotspotter secret.

C. SHOTSPOTTER SENSORS



Figure 6. Shotspotter Sensor (From: Shotspotter Inc. Military Capabilities PowerPoint)

The sensors themselves (Figure (6)) are designed to be man-portable, vehicle mounted or fixed in position. They are 4 inches by 5 inches and weigh 1-2 lbs each. Each Shotspotter sensor has its own identification code that can be recognized by the central Shotspotter base station in order to triangulate the direction of a gunshot. When the central base station receives reports of gunshot detections, the locations of the reporting sensors are

cross referenced. The Shotspotter terminal then calculates and displays all the information (Figure (7)) related to the gunshot as perceived by the sensor— time, location etc.

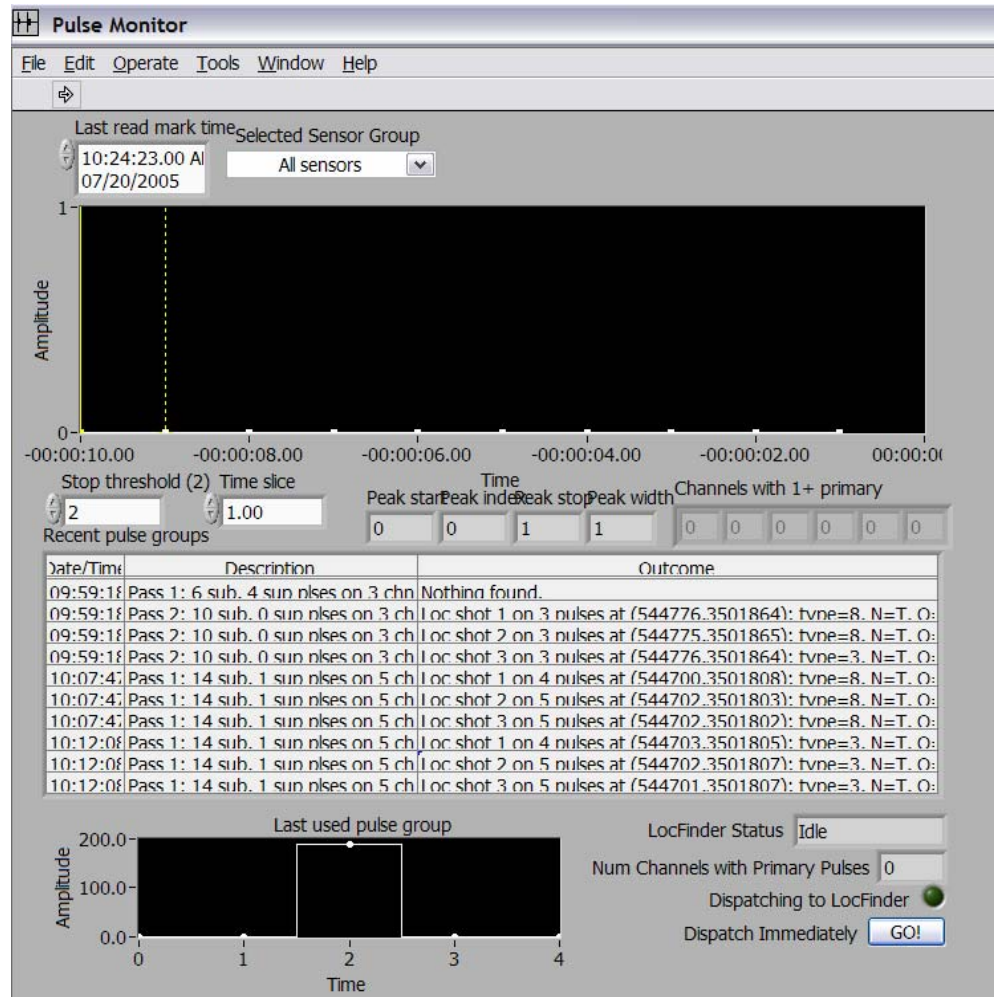


Figure 7. Shotspotter Central Base Station Data Table
(From: Shotspotter Base Station Screen Capture, 18 July 2005)

If more than three Shotspotter sensors detect a gunshot, it is possible to have multiple triangulated locations. To determine which trio of sensors has the best triangulated location, the data will be tested according to the following criteria:

1. Select the three sensors which give the greatest number of confirming impulses from other sensors.

2. Select the three sensors which produces the most widely-spread direction vectors to the event (and hence the most geometrically robust solution).
3. Select the three sensors which have the highest sum of acoustic sharpness.
4. Select the three sensors which give, among the calculated locations from all possible triads, the most central location.²⁷

D. SHOTSPOTTER LAYERED PROTECTION

Shotspotter sensors are designed to be used in three configurations that provide deep protection. The last layer, layer 3, is called semi-fixed because it is mostly immobile. This layer would be used to detect gunfire in fixed positions such as a base camp or pre-positioned urban environments. This layer has the widest acoustic aperture and is the best at countering the effects of echoes. Figure (8) shows the three layers.

²⁷ Shotspotter Patent.

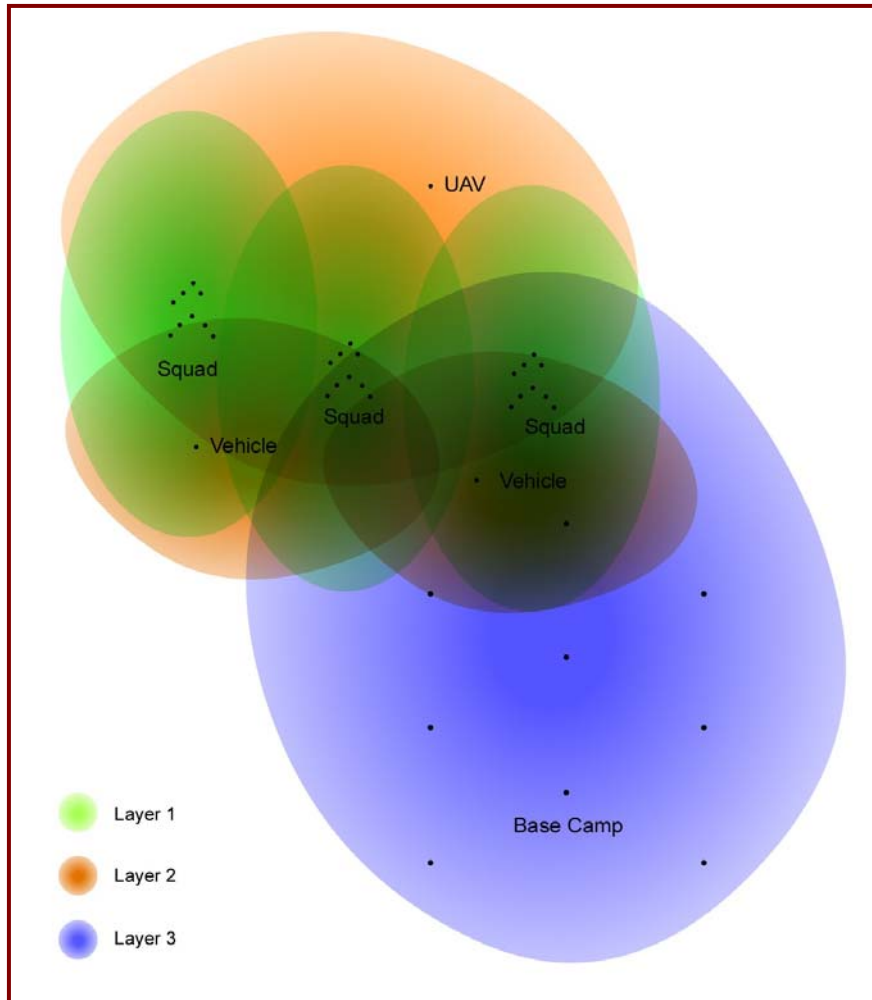


Figure 8. Shotspotter Sensor Layer Model (From: Shotspotter Inc. Military Capabilities PowerPoint)

The next layer, layer 2, is the mobile unit protection layer where Shotspotter sensors are placed on vehicles, UAVs, or aircraft. This layer provides increased mobility when using Shotspotter sensors while maintaining a relatively wide acoustic aperture. An interesting advantage to this layer is three-dimensional detection when Shotspotter ground sensors are used in conjunction with airborne Shotspotter sensors. Since the sensors are normally all on the ground, they are essentially on a two-dimensional plane, so height effects are negligible. When sensors are also detecting gunfire from the air, however,

the sensors are able to provide height as well as a GPS location.

The first layer, layer 1, is the squad level layer. This layer is used for maximum mobility at the squad level. This layer has the smallest acoustic aperture and is used for tactical deployment. While this layer is the most likely to be most useful to our forces, it unfortunately has the most limitations of all the layers. In addition to reduced aperture, this layer has a number of inherent human factors. For example, E-6 and below Marines who were using the Shotspotter sensors in Extended Awareness I had some of the following comments about carrying the sensor:

- Sensor is too big.
- Difficult to mount to the web gear and then turn on or make sure that the system is working.
- The clips on the back of the case are weak and some broke.
- The on/off switch needs to be outside of the case and when the system is on, all sensor info should be sent to the watch so we know it's on and functioning.
- Radio range is way too short.
- Is there a way to track the individuals while in a building/bunker/tunnel?
- Remove all sharp edges from the case²⁸

E. SHOTSPOTTER AS A BLUE FORCE TRACKER

Shotspotter sensors are each equipped with a GPS sensor that relays its location back to the central base station in a continuously updating data stream. While this function requires a respectable amount of computing, it is necessary to compute locations when a gunshot is fired.

²⁸ Shotspotter Inc. Military Capabilities PowerPoint.

Since the triangulation calculations are dependent on the locations of the best three sensors around, their exact GPS locations must be known at all times in order to accurately locate a gunshot. While GPS sensor data is necessary to perform the core Shotspotter functions, Shotspotter's usefulness as a tracking mechanism is apparent as an input to the Common Operating Picture (COP).

Shotspotter is not, by definition, a blue force tracker, since it relies on its own local network for tracking and data transmission. Shotspotter sensors do not have the capability to transmit their location past a few kilometers—let alone up to a satellite for centralized data compilation. Shotspotter sensors are, at the very least, relatively cheap (about \$5000 per unit, but drastically cheaper if put into mass production) and could provide good tracking on a local network. For example, if every member of a unit were equipped with a Shotspotter sensor, then the unit commander would have a good view of where all his forces were since they would appear on his COP. In this sense, Shotspotter sensors offer the potential to perform the same functions as a blue force tracker, but on a smaller level.

III. EXTENDED AWARENESS

A. EXPERIMENT

1. Overview

Extended Awareness is a series of experiments conducted by the Joint Operational Test Beds System (JOTBS) under the United States Joint Forces Command (JFCOM). The experiments are designed to integrate a number of emerging technologies for potential use by the DoD. As the name might imply, Extended Awareness is focused on bringing about a greater sense of situational awareness in the battlespace. To enable battlespace awareness a great deal of man portable, stationary, and automated sensors must be integrated with a single objective in mind: enhance our war fighting capabilities through improved situational awareness and shared information.

2. Key Technologies

Extended Awareness tested many different technologies. Some of the key technologies were:

- Shotspotter- acoustic gun sensor described in detail in Chapter II.
- Cursor on Target (CoT) - CoT takes geographic information from all sensors involved in the experiment and shows them on a real-time COP (FalconView). CoT uses a XML schema to perform data transmission.
- ScanEagle - A small (40 lbs.), Boeing owned and operated, Unmanned Aerial Vehicle (UAV) that has advanced Electro-Optical (EO) and Infrared (IR) sensors.

- Unattended Ground Sensors (UGS) - An underground sensor, owned and operated by Neptune Sciences Inc., that detects events such as moving vehicles.
- The Joint Mission Support Module (JMSM) - A command module housed in a trailer. The JMSM has the greatest amount of displayed information and provides the greatest situational awareness- this is where the mission commander is located. The JMSM shows the FalconView, real-time UAV video, among other situational awareness tools.
- Collabcast - Provides a two-way, IP based broadband capability that is similar to the Global Broadcast System (GBS). This allows streaming video, chat, and situational awareness to be shared throughout the system and to reach-back locations.
- Fusion Technology Test Bed (FTTB) - This is a center for data fusion and integration. The FTTB will take information from the rest of the network and fuse it with other actionable information from a variety of other centralized intelligence mediums.

B. EXTENDED AWARENESS I

Although this thesis is primarily concerned with actions taking place during Extended Awareness II and Extended Awareness IIB, experiment results from Extended Awareness I are still important because the Extended Awareness experiments are a series.

Extended Awareness I took place in New Orleans, LA area from 3-16 December, 2004. The experiment was conducted in conjunction with the U.S. Marine Corps 26 Marine Expeditionary Unit (MEU) Training in Urban Environment Exercise (TRUEX). Extended Awareness I was a dissimilar unmanned aerial vehicle experiment conducted in order to test technical integration capabilities of ground sensors into the advanced sensor and situational awareness network established during the Forward Look experiment series (e.g., Cursor on Target (CoT)) augmented with additional innovative capabilities to enhance UAV system interoperability.²⁹

Extended Awareness I was primarily a risk mitigation event to surface and work through problems that might arise in the Extended Awareness II and Extended Awareness III experiments.

C. EXTENDED AWARENESS II

1. Overview

Extended Awareness II (EA-II) took place in Ft. Huachuca, AZ from 11-22 July, 2005. EA-II was a live fire exercise that built upon EA-I and was designed to add to data concerning the effectiveness of the integrated sensors and intelligence platforms to provide improved situational awareness.

2. Information Flow

Data from various sensors, such as Shotspotter, was fed back to the Cursor on Target server where it could be compiled into a common operating picture. Using data transmitted in XML format, the COP information was

²⁹ Joint Operational Test Bed System (JOTBS) Extended Awareness 1 (EA 1) Quicklook, 30 December 2004.

displayed on a software system called FalconView and was processed through the data flow as shown in Figure (9).

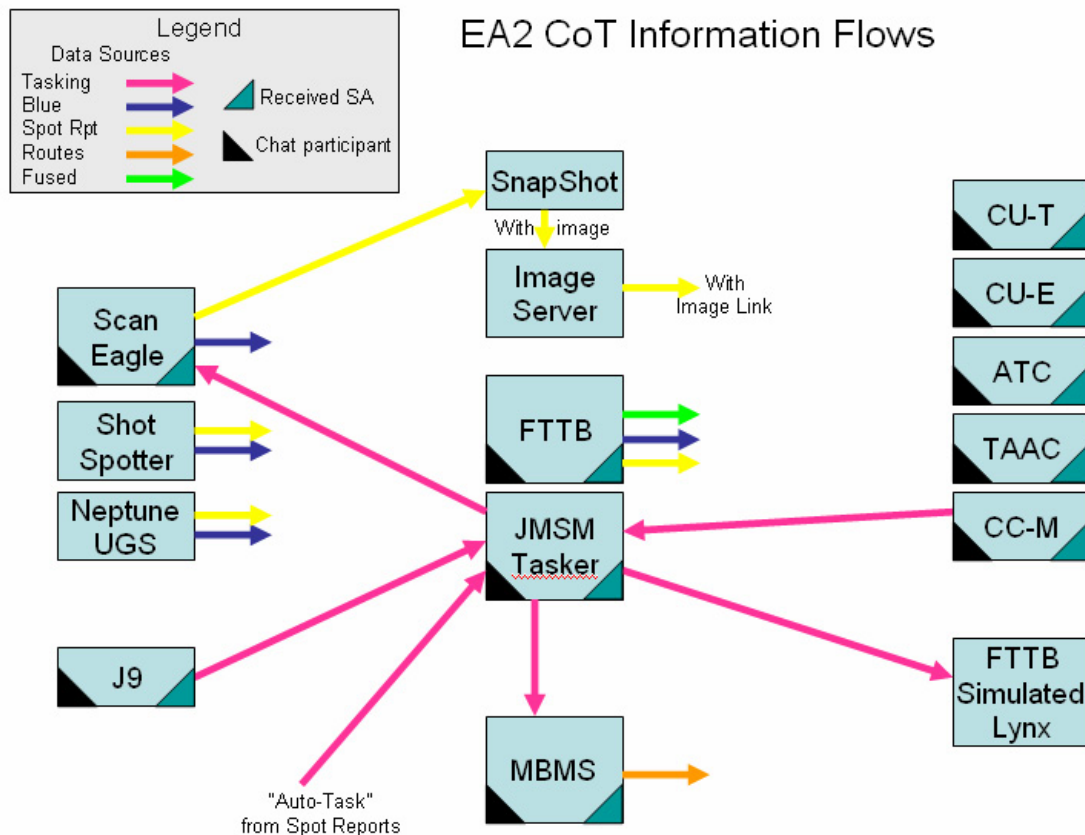


Figure 9. EA-II Information Flows (From: U.S. Joint Forces Command)

This common operating picture was then given to the JMSM for analysis. Data from the JMSM was given to the FTTB so that it could be fused with intelligence that was either on hand at the FTTB or available via regular internet at a centralized location somewhere else in the world. Once intelligence had been added to the COP, a SALUTE report (Size, Activity, Location, Unit Description, Time and Date, Equipment) was given back to the "Blue Team" convoy vehicles.

If the data coordinates were correct, and the system technology worked effectively, the ScanEagle UAV would slue

its camera and IR sensors to the location of interest. The live video feed could be seen in both the JMSM and FTTB trailers for cross reference with the COP. An example of the FalconView COP is shown in Figure (10).

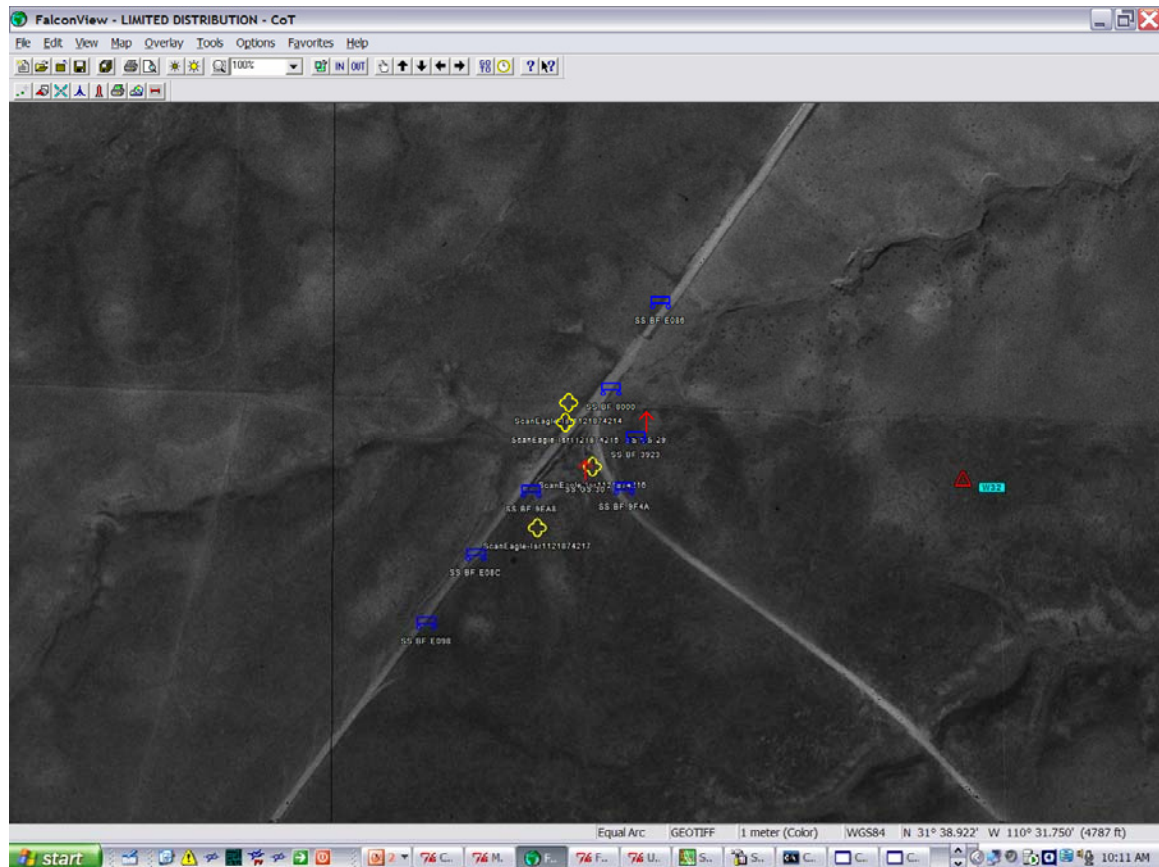


Figure 10. FalconView COP (From: FalconView COP Screen Capture 18 July 2005)

3. Extended Awareness II Architecture

In order to enable information sharing throughout the Extended Awareness network, a great number of different systems had to be integrated. The overall system architecture is shown in Figure (11).

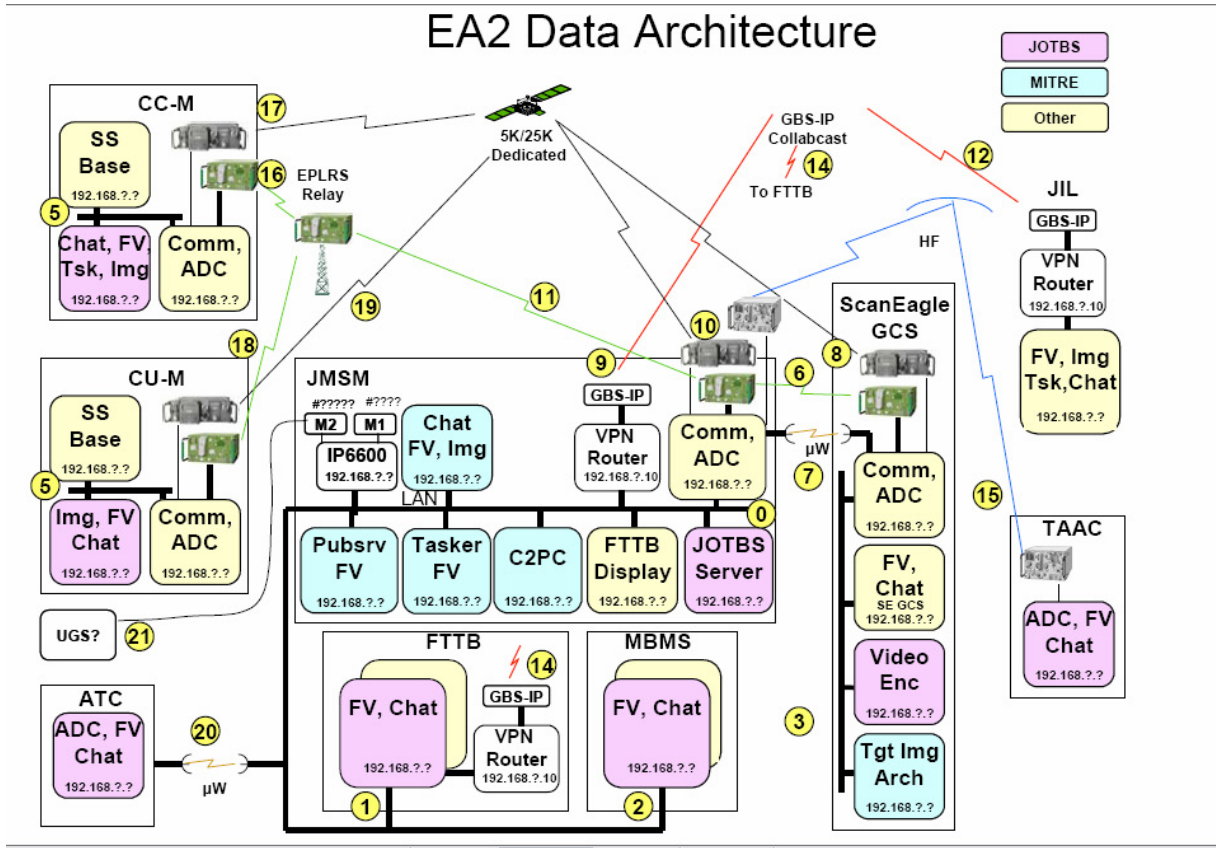


Figure 11. EAII Data Architecture (From: U.S. Joint Forces Command, Test Plan for Extended Awareness 2)

The details of the system shown in Figure (11) are beyond the scope of this thesis. These network connections, however, are critical in understanding why network latency can be a problem. The next figure (Figure (12)) shows the robustness of the network and its ability to be adaptable.

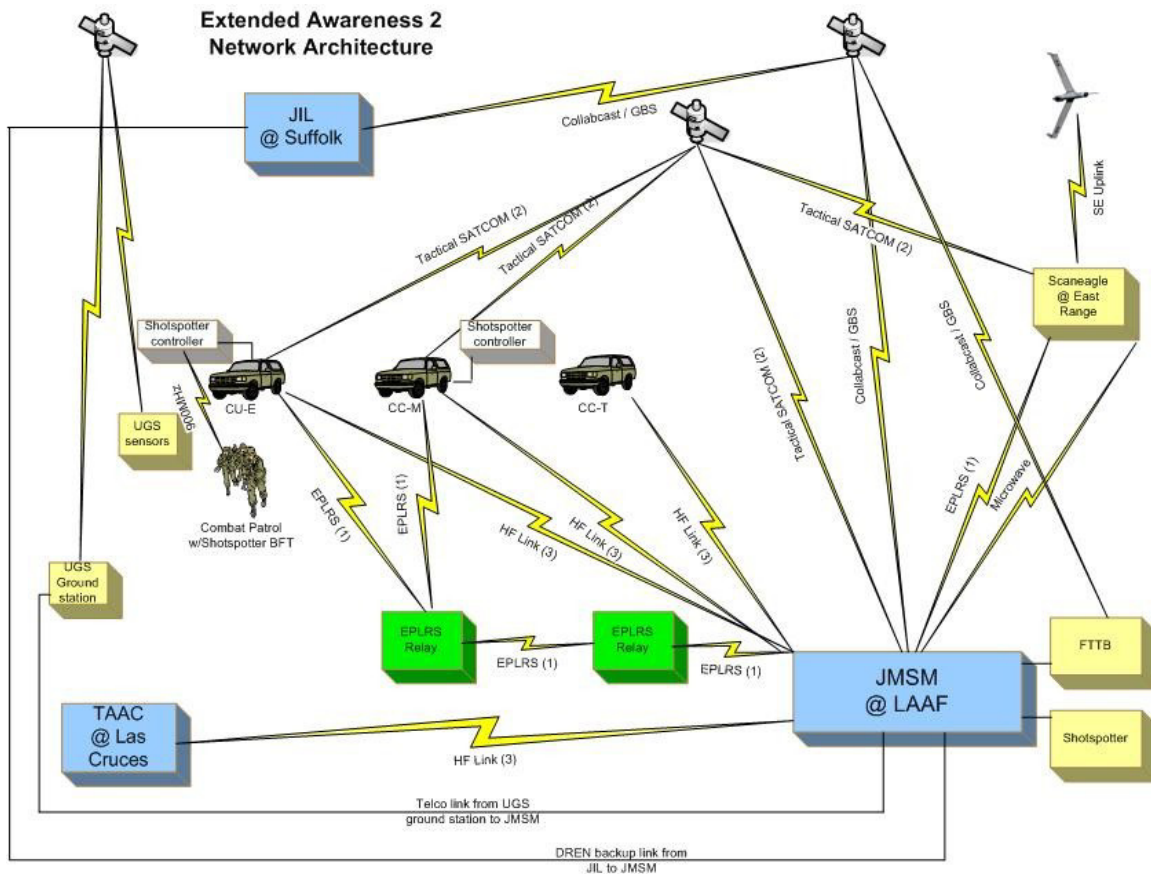


Figure 12. Network Connectivity Architecture, EAIL
 (From: U.S. Joint Forces Command, Test Plan for
 Extended Awareness 2)

Of note above are the different mediums by which data can be transferred. While the local Shotspotter network always works on a 900 MHz radio connection, the uplink back to a central data collector was accomplished through three different data transfer systems: Enhanced Position Location Reporting System (EPLRS), Tactical Satellite (TACSAT), and High Frequency Radio (HF). Each of these communications systems are shown in Figure (12), although they were tested independently and never used at the same time. Each of they systems has its own advantages and disadvantages that will be explored in greater detail in the Observations section of this thesis.

D. EXTENDED AWARENESS II-B

1. Overview

Extended Awareness II-B (EA-IIB) took place in the Yuma Proving Grounds (YPG), Yuma, Arizona from 27 to 28 July 2005. EA-IIB used almost exactly the same systems technology as EA-II, but collected data with respect to an additional parameter: mortar detection and location. Shotspotter has been used almost exclusively as a sensor to detect and locate gunshots. Detecting a gunshot is relatively easy due to the loud and abrupt nature of a bullet explosion. A mortar is different because it has a slower, less abrupt sound signature. By placing an array of sensors around a mortar firing position, it was theorized that Shotspotter could locate and identify an enemy mortar. To do this, ScanEagle orbited at approximately 1500 feet over a pre-determined mortar firing location in as shown in Figure (13).

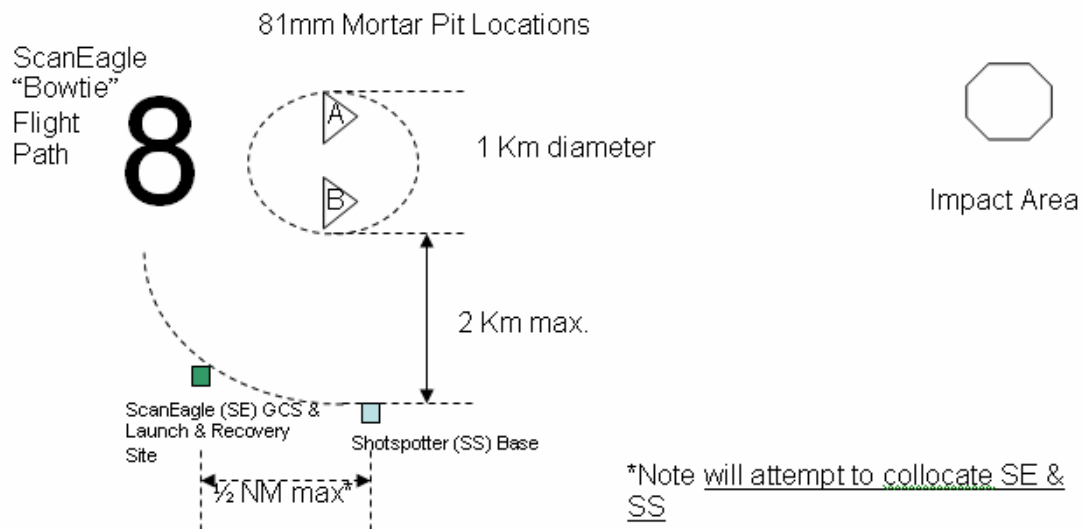


Figure 13. Mortar Firing Plan EA-IIB (From: U.S. Joint Forces Command, Test Plan for Extended Awareness 2B)

In addition to Shotspotter, Cursor on Target, FalconView, and ScanEagle mentioned in the EA-II section, EA-IIB also used technologies called VICE and LOGIR:

- Video Imagery Capability Enhancement (VICE): VICE is a PC-based capability that processes video imagery and data from sensor platforms (independent of the sensor platform) and provides the operator/analyst with more precise target geo-location accuracy and greater situational awareness. VICE improves on the down linked metadata information to improve geo-location accuracy. VICE provides mosaic displays of the video imagery and geo-registers the video imagery to underlying reference imagery. VICE can receive and output sensor platform data via Cursor on Target (CoT) interface. The VICE operator creates target folders with target location image and five tie point coordinates for "man-in-the-loop" targeting solutions or export the target folder to a mensuration tool to obtain precision guided munitions accuracy coordinates. The mensurated coordinates are exported via CoT to complete the targeting process.³⁰
- LOGIR (Low-cost Guided Imaging Rocket) was the kill mechanism simulated by a research team based out of China Lake, California. The team would take coordinates given to them by the VICE team and would use a simulation to kill the target. To do this, the VICE team had a computer model of the area and a computer model that simulated controlling a Predator UAV armed with a LOGIR.

2. Information Flow

Much like the EA-II experiment, once a gunshot/mortar event was detected, the information was processed as quickly as possible through the established network. The network data architecture is depicted in Figure (14):

³⁰ U.S. Joint Forces Command, *Concept of Operations (CONOPS) and Test Plan for Extended Awareness 2B*. 2005.

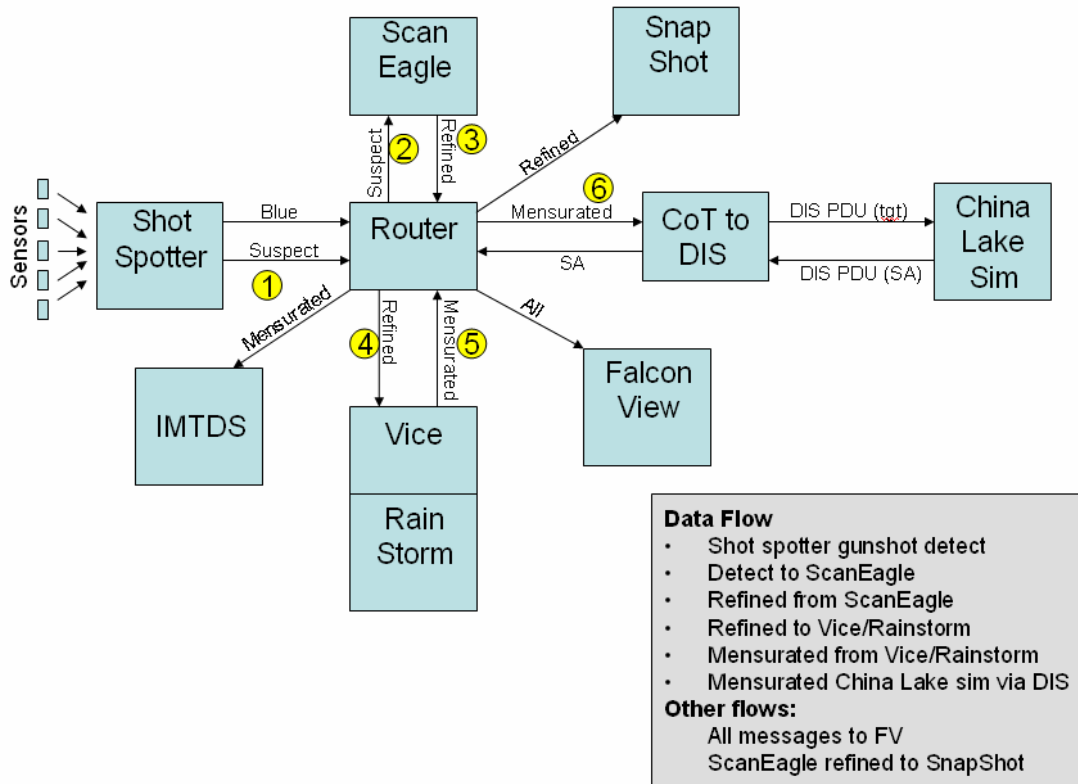


Figure 14. Yuma "CoT OODA" Architecture (From: U.S. Joint Forces Command, JOTBS)

3. Extended Awareness II-B Architecture

EA-IIB used a much simpler architecture than EA-II primarily because it didn't have nearly as many testable parameters. EA-IIB tested only two major parameters: 1) Shotspotter's ability to detect and locate a mortar firing position, and 2) the amount of time it would take to eliminate the threat. Therefore, the architecture to support such an endeavor could be much more local, and require much less support from outside organizations. In fact, there was no internet connectivity available in the YPG testing area. Figure (15) shows the EA-II architecture in its most basic form.

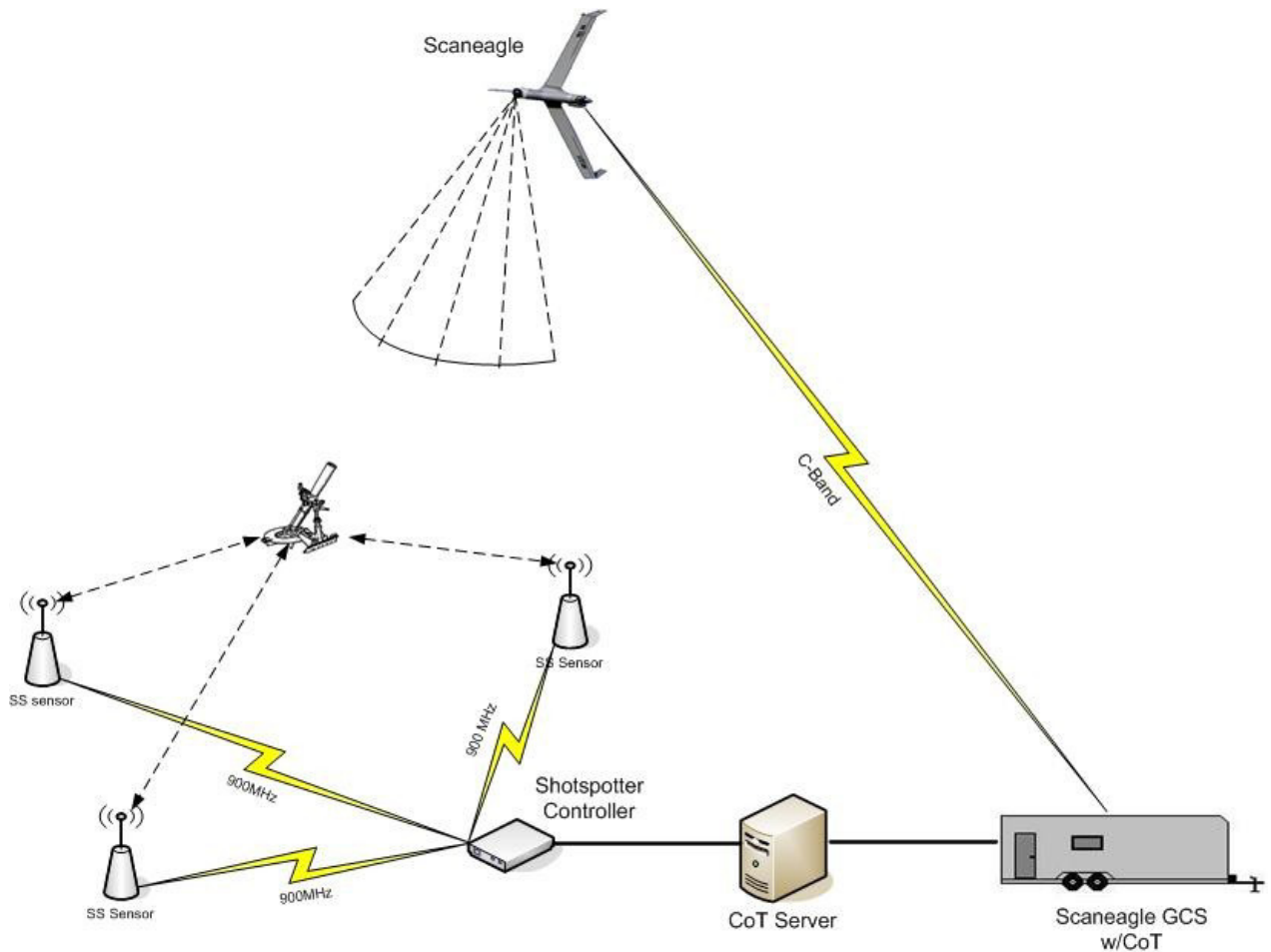


Figure 15. EA-IIB Communications Architecture (From:
From: U.S. Joint Forces Command, Test Plan for
Extended Awareness 2B)

To further simplify potential problems, a copper cable provided connectivity between the Shotspotter controller and the CoT server. This reduced the likelihood that connectivity would become a problem due to the intrinsic difficulties of trying to setup a high-bandwidth, reliable network in a short period of time.

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IV. DATA AND OBSERVATIONS

A. EXTENDED AWARENESS I DATA

1. Quantitative Data

During Extended Awareness I, Shotspotter had a fairly impressive showing and demonstrated its ability to detect and locate gunfire. Since the actual GPS locations of the mortar firing positions were pre-determined, Shotspotter locating parameters were quickly compared to these positions to show error. Figure (16) shows the amount of error Shotspotter reported when locating the mortar firing positions.

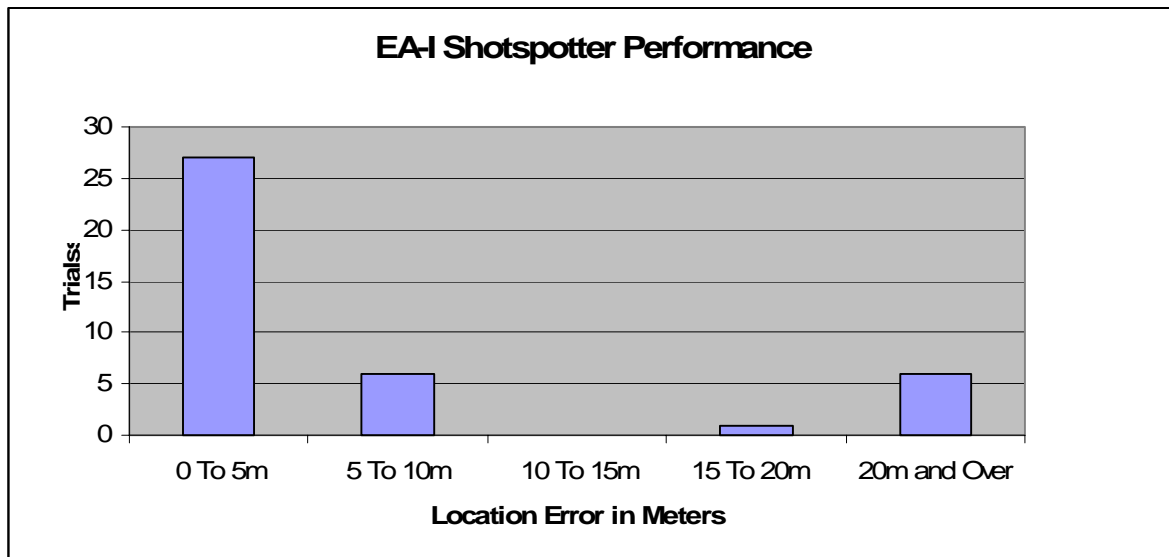


Figure 16. EA-I Shotspotter Performance (From: Extended Awareness 1 Quicklook)

2. Qualitative Data

In EA-I, Shotspotter would detect a gunshot and send that information back to FalconView so that ScanEagle could slew its cameras to the location of interest. ScanEagle's cameras scan an area approximately 100 meters by 100 meters, so Shotspotter errors fewer than 20 meters away from the actual gunfire location were considered

successful. According to the data collected at EA-I, Shotspotter correctly detected and located gunfire 85% of the time. An interesting caveat along with this data is how well the rest of the system worked. Even with 6 outliers, Shotspotter averaged only 14 meters error for the 40 recorded shots. ScanEagle's camera slew was, on average, 27 meter off of the actual target coordinates. The difference between each of the Shotspotter locations and the location that ScanEagle slewed to was, on average, 16 meters. This tells us that, with the exception of the outliers, Shotspotter located the target more effectively than ScanEagle. This data also shows us that ScanEagle is not as accurate as Shotspotter, but ScanEagle is limited by the data that it is fed by Shotspotter. Ultimately, ScanEagle will only work as well as Shotspotter, so Shotspotter location data is the most critical data in the experiment.

B. EXTENDED AWARENESS II DATA AND OBSERVATIONS

1. Overall

Data collection at EA-II was inconsistent because of the revolutionary nature of the experiment. There are no set tables revealing how well Shotspotter worked for the experiment because the experiment was primarily for demonstration purposes. For the most part, Shotspotter sensors detected the gunshots and the events appeared on FalconView. On one of the firing events, it took approximately 3 minutes 30 seconds from the time a shot was fired to the time the convoy received a detailed SALUTE report. Shotspotter worked very well from a qualitative standpoint with only minor problems.

One example of Shotspotter's shortcoming occurred on 18 July at approximately 1100. Shotspotter reported a location that was some 123 meters away from the actual location during a series of shotgun firing events. The error reported here turned out to be human error in sensor augmentation. Shotspotter's representative at EA-II had noticed a 4 degree Celsius change in the ambient temperature indicated by the Shotspotter sensors and manually adjusted the Shotspotter temperature sensors to the old reading. The representative assumed that a 4 degree change was improbable considering that the temperature change took place between firing events (approx. 30 minutes). To correct this presumed error, the representative the temperature reading by hand to the old temperature. Since sound travels differently through air at different temperatures, the alteration in the temperature gage caused the sensors to give a location that was out of view of ScanEagle and unusable for any tactical purposes.

2. EA-II EPLRS Network

The EA-II experiments used three different communications mediums to transmit data to and from the convoy. EPLRS (Enhanced Position Location Reporting System) was used to transmit data to and from the convoy, overall, this system turned out to be an effective way to transmit all the data required to successfully conduct the experiment. However, for approximately 15 minutes, the system lost all connectivity for reasons unknown and the convoy came to a complete halt in order to reestablish contact with the JMSM³¹. Once the system was up and running

³¹ This was taken from Elliott observation, available on the NPS FIRE KM System under "SS Log 7".

again, the Blue Force Tracking element of Shotspotter was still failing and worked sporadically for the remainder of the day.

Although the EPLRS system was able to handle the data loads effectively and only had one instance of lost connectivity, there are a few intrinsic problems with the EPLRS system. EPLRS requires relay stations since it is a line of sight connection. This means that relay stations will almost always be required to conduct operations-requiring additional people, training, and equipment. Moreover, the relay stations themselves would be endangered due to being placed the frontline and the JMSM.

3. EA-II TACSAT Network

The second day a 5K TACSAT connection was used to transmit all the data to and from the convoy. Although the local Shotspotter network was able to detect many of the shots, very few of them ever appeared on FalconView due to the latency associated with a 5K bandwidth network. In more than two firing events, Shotspotter data took well over 30 seconds to appear on FalconView.³² The network latency was such an issue that confusion arose about which events were taking place because events would appear sporadically on FalconView.

Furthermore, genuine situational awareness was never fully achieved due to a failure by ScanEagle to become airborne, due to a fuel problem that was later corrected. Nevertheless, ScanEagle was scheduled to launch at approximate 0630 and didn't actually become airborne until 1104. Once ScanEagle was up and flying, network latency issues plagued the experiment and several more firing

³² Available on the NPS FIRE KM System, under "Data Log, JMSM 7-19C".

events took in excess of 30 seconds to appear on FalconView.

TACSAT, however, did have an advantage of nearly unlimited coverage and didn't require a forward-deployed relay vehicle, but TACSAT during EA-II had insufficient bandwidth to transmit the amount of data needed to successfully conduct operations.

4. EA-II HF Network

On the last day of experimentation, Wednesday 20 July 2005, HF radio was used to transmit the data to and from the convoy vehicles. In terms of bandwidth constraints and network latency, HF was by far the worst of all the network communications mediums. In addition to bandwidth issues, the entire convoy was not able to deploy on time due to HF connectivity problems. Once the problems were fixed, HF proved to have the worst latency of all the networks, with firing events appearing on FalconView well over a minute after happening. The HF network did not require satellites or relay stations because it does not require a line-of-sight connection to the convoy. HF uses reflection off of the ionosphere as well as the earth's surface for communicating, but most involved with EA-II agreed that HF simply didn't have enough bandwidth to work effectively.

C. EXTENDED AWARENESS II-B DATA AND OBSERVATIONS

1. Overview

EA-IIB was a far simpler test and had far fewer measurable parameters since the primary objective of EA-IIB was to test Shotspotter's ability to detect and locate mortar fire. The test plan for EA-IIB called for 24 different mortar firing events. Each event the number of

rounds fired, the charge used in firing, and the location of the firing position was varied.

2. Problems

Although the test plan appeared to be nearly perfect, a series of problems almost stopped the entire experimentation process. The first, and biggest, problem in EA-IIB, was that the Shotspotter sensors were upwind of the mortar firing positions. Heavy winds pushed most of the mortar's acoustic energy downwind, away from the Shotspotter sensors. The result was that the Shotspotter sensors were unable to detect any of the preliminary mortar shots. On the few occasions where Shotspotter was able to detect the mortar shots, the three detecting sensors were receiving different information due to the wind. The winds were sustained at approximately 15 knots with gusts up to 20 knots, and were strong enough to make Shotspotter sensor useless. To fix the problem, the Shotspotter sensors were moved. Since the wind was blowing from the South-West, the sensors were moved to the North-East, as shown in Figure (17). The Red arrows indicate the location of the old sensors, and the yellow arrow indicates approximate wind direction and velocity at the time of the experimentation. The Blue boxes represent the new Shotspotter sensor locations. The two hourglass figures represent the flight path of ScanEagle over the mortar firing pits.

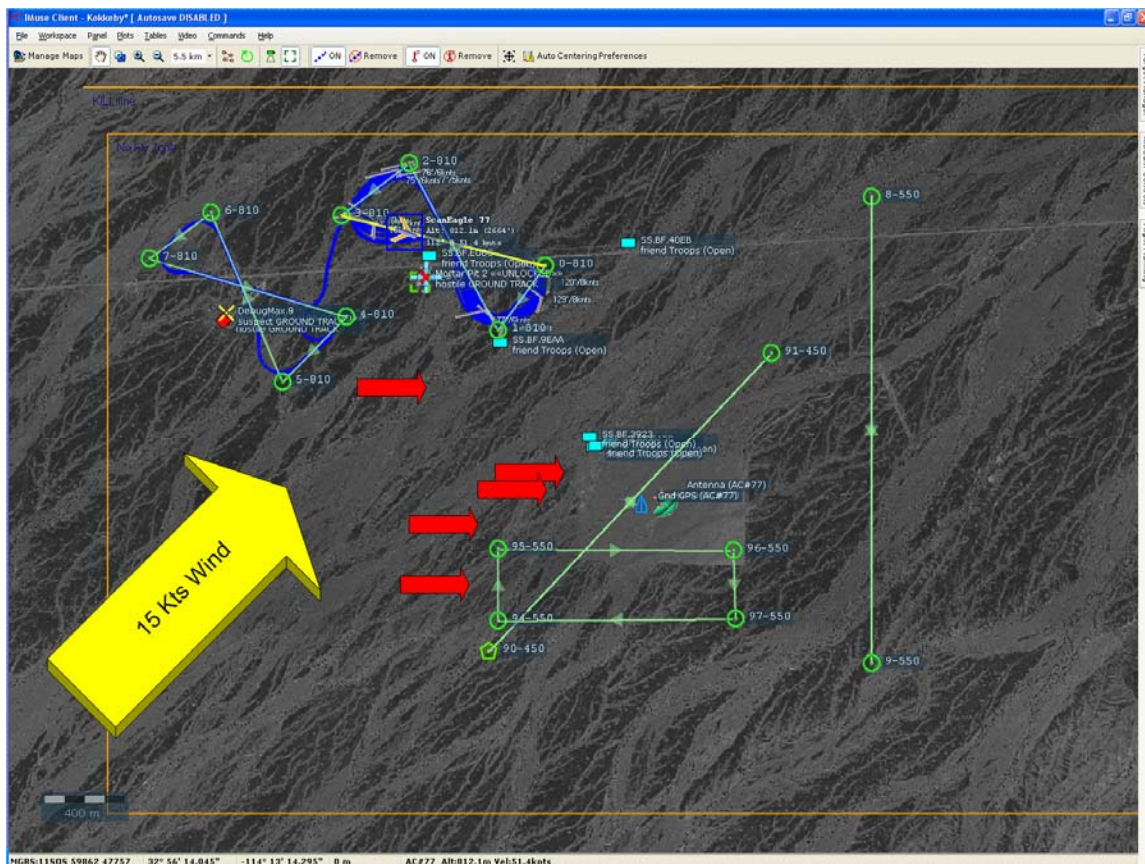


Figure 17. Sensor Movement (After: FalconView screen capture, 28 July 2005)

3. Results

Once the Shotspotter sensors were moved, data collection went rapidly. Experiment operators abandoned the idea of varying mortar charges and opted for a more Ad hoc approach. Since the range closed for the day at approximately 1530, a day's worth of data collection was squeezed into about an hour—the results of which are shown in Table (1).

| Event # | # Mortar Rounds/Event | Propellant Charge/Round | Shoot Time (Local Time) | Shotspotter Report (Total Elapsed Time) | ScanEagle Report (Total Elapsed Time) | VICE & Rainstorm (Total Elapsed Time) | LOGIR <u>Impact</u> Time (Total Elapsed Time) | Comments |
|---------|-----------------------|-------------------------|-------------------------|---|---------------------------------------|---------------------------------------|---|--|
| 1 | 3 | 3 | 14:17:53 | 0:00:13 | 0:00:53 | 0:02:47 | 0:03:08 | |
| 2 | 3 | 4 | 14:23:00 | | | | | Detected, Not Located. Estimated 10-15kts winds. |

| | | | | | | | | |
|----------|----|---|----------|------------------------|----------------|----------------|----------------|--|
| 3 | 3 | 4 | 14:24:20 | | | | | Detected, Not Located. |
| 4 | 1 | 4 | 14:26:20 | 0:00:08 | 0:00:51 | Missed | 0:04:19 | Calm Wind |
| 5 | 3 | 3 | 14:29:50 | 0:00:05 | 0:00:47 | 0:02:50 | 0:03:50 | Calm Wind |
| 6 | 3 | 3 | 14:34:17 | 0:00:11 | 0:00:48 | Missed | 0:03:31 | Calm Wind |
| 7 | 3 | 2 | 14:44:05 | | | | | Detected, Not Located |
| 8 | 3 | 4 | 14:45:20 | 0:00:07 | 0:00:38 | 0:03:20 | 0:04:13 | Vice Reboot |
| 9 | 3 | 4 | 14:50:00 | 0:00:08 | 0:00:30 | 0:02:13 | 0:02:49 | |
| 10 | 3 | 4 | 14:53:28 | | | | | Detected, Not Located |
| 11 | 3 | 4 | 14:54:35 | | | | | Flyer 1km NE |
| 12 | 3 | 4 | 14:56:20 | | | | | Detected, Not Located |
| 13 | 3 | 4 | 14:57:34 | | | | | Winds SE 10-15 Kts Detected, Not Located |
| 14 | 3 | 4 | 14:59:18 | | | | | Response to other Acoustic Event (Ammo truck tailgate) |
| 15 | 4 | 4 | 15:02:30 | 0:00:15 | 0:00:46 | 0:02:00 | 0:03:28 | Detected, Not Located |
| 16 | 4 | 4 | 15:08:22 | 0:00:15 | 0:00:52 | 0:02:25 | 0:03:38 | Slightly Outside ScanEagle FOV |
| 17 | 4 | 4 | 15:12:30 | | | | | Detected, Not Located |
| 18 | 4 | 4 | 15:14:00 | | | | | Detected, Not Located , Wind |
| # Event: | 18 | | | <u>Average Results</u> | | | | |
| # Rds: | 56 | | | 0:00:10 | 0:00:46 | 0:02:36 | 0:03:38 | |

Table 2. EA-IIB Data Table (From: U.S. Joint Forces Command, Joint Operational Test Bed System (JOTBS))

Here we see that Shotspotter only successfully detected and located a mortar firing position approximately 44% of the time. Also, averaging 3 minutes and 38 seconds, the turnaround time from target detection to target destruction was less than impressive, shown in Table (2).

| <u>Event</u> | <u>Time (Average)</u> | <u>Range</u> |
|---------------------------------|-----------------------|---------------|
| Shotspotter Report to ScanEagle | 10 seconds | 5-13 Seconds |
| ScanEagle ID & Refinement | 46 seconds | 30-53 Seconds |

| | | |
|---|-------------------------|---|
| VICE Geo-Registration & Rainstorm Target Geo-location | 2 Minutes 36 Seconds | 2 minutes 30 seconds – 3 minutes 20 seconds |
| | | 2 minutes 49 seconds - |
| LOGIR Impact | 3 Minutes 38 Seconds | 4 minutes 19 seconds |

Table 3. EA-IIB Compiled Data (From: U.S. Joint Forces Command, Joint Operational Test Bed System (JOTBS))

B. EXPERIMENT COMMENTS

1. EA-2

The results from EA-2 are suspect because of the manner in which the sensor data was collected. While there were Shotspotter sensors on every convoy vehicle, the major source of sensor data came from pre-positioned Shotspotter sensors that were placed in an almost circular array around the gunshot firing position. Shotspotter's recorded error rate was extremely good, but legitimate convoy detection capabilities remain uncertain. In addition to using a pre-positioned sensor array around a gun firing position, the convoy vehicles were always at a complete halt for the shootings.

The Shotspotter sensors worked very well under the conditions used in EA-II. Nevertheless, the conditions in which the sensors were used are not likely to exist in a real combat situation.

2. EA-III

Currently, Shotspotter is not an effective device for detecting mortar fire. With an optimal detection rate of less than 50 percent, Shotspotter will need further development before reliably detecting mortar fire. Also, its worth noting that the results regarding Shotspotter's effectiveness are indicative of Shotspotter results after the sensors were moved to optimize the movement of acoustic

energy around the mortar firing pits due to heavy winds. Before the move, the Shotspotter sensors were not able to detect any of the mortar fire. Again, this denotes a reliance on optimum conditions for successfully locating a mortar firing position, conditions that will almost certainly be absent from an actual battlefield.

3. Overall

When it worked, Shotspotter was an extremely impressive and powerful tool that could help our troops tremendously. While the Shotspotter system, and the network that supports it, need additional research and development, the capabilities that Shotspotter brings to the table are impressive to say the least. As a situational awareness tool, Shotspotter's concept is great.

V. CONCLUSIONS

A. SHOTSPOTTER AS AN EDGE TOOL

Shotspotter certainly has the potential to become a very valuable tool for edge actors. The goal in applying this law-enforcement technology to military applications is to give added capabilities to the tactical units actually under gunfire. The ability to quickly and precisely locate the position of an enemy is a capability that will enhance our edge units' ability to quickly react to unexpected threats. This is especially true in the urban, asymmetric warfare that our military is likely to continue to face in the future. This capability will make edge organizations much more agile, allowing them to quickly orient themselves on the battlefield. Furthermore, the blue force tracking capability of the system can be a great aid in preventing fratricide in the future. Shotspotter can definitely become a technology enabler in Information Age operations, but it will require the further refinement of the system.

The main issue limiting Shotspotter as an edge tool is the method in which it disseminates information. Currently Shotspotter acts specifically as a tool to the commanders in tactical situations. There is no effective dissemination of the information gathered by Shotspotter to the real edge actors. While there Shotspotter does display information on the base station, further dissemination of the information is done by tactical voice communications. This limits the role that the system can play in an edge organization. Shared situational awareness is one of the key tenets of self-synchronization. Currently Shotspotter does not share

situation awareness in a fashion that will suit a truly edge-organized military.

The advances to make Shotspotter a valuable tool to edge actors are mainly hindered by technology. There must be a way to instantly share the information gathered by the base station with all the members of an edge unit. Shotspotter Inc. has developed a wrist watch that displays key information on it, but this has had mixed results. The Marines that tested the system with the watch during EA I made note that the watch just wasn't helpful enough. The creation of a new system for information distribution or the improvement of the watch should be a key goal of future system generations. The concept of the watch display unit is certainly in line with the concepts of *Power to the Edge* but there must be further development. Technology will limit this development until there is more bandwidth, better display units and a higher reliability in the location provided by Shotspotter.

B. EXTENDED AWARENESS AS AN EDGE EXPERIMENT

The Extended Awareness series of experiments has gone a long way in increasing the use of helpful technology on the future battlefield. It has definitely fielded a number of systems that could be invaluable to edge actors during future operations should our military transform itself into and edge organization. However, if this is to happen, then experimentation must be aligned with the concepts of *Power to the Edge*. This section will create a picture of what EA II would look like if it had been organized by *Power to the Edge* principles as opposed to those of FCBA. Before getting into the proposed changes to the EA II architecture, it

should be noted that since *Power to the Edge* is a forward looking document, some of the changes require bandwidth that is not available with current technology.

The main change to EA II would have been to shift the focus of activity from the JMSM to the actual convoy. EA II was set up in traditional hierarchical fashion, with the mission commander directing his units through a convoy situation. As there were changes in events, the mission commander would relay new orders to the convoy throughout the experiment. To be an edge experiment there would have been a set mission for the convoy, i.e. delivery of supplies, show of force, reconnaissance, with a defined commander's intent and previously developed ROE. The convoy would have been sent on the mission, entrusted to adapt to threats they encountered on the convoy route. The role of the mission commander would have been to monitor the convoy and dynamically change the mission objectives or ROE as he saw fit. His direct control over the convoy would have been limited though. This would have increased the agility of the convoy to deal immediately with situations that arose in a manner in line with the commander's intent and ROE.

Another change to the experiment would have been the creation of better situational awareness in the convoy. The main aim of EA II was to maintain excellent situational awareness for the mission commander and then pass down the intelligence and orders he deemed important to the convoy. If it had been an edge experiment, the goal would have been to have the technology in place to maintain excellent situational awareness in the convoy. Then the members of the convoy would dynamically network to sensor assets as they deemed necessary. This would create information flows

that were "horizontal, independent of chain of command" as envisioned in *Power to the Edge*.³³

In practical terms, this horizontal information flow would mean the ability of the convoy to directly connect to resources for sensor information or intelligence. Specifically the convoy commander would be able to network with the ScanEagle ground control station to request information that he deemed necessary to mission accomplishment. This would require the creation in the experiment test plan of a number of different situations along the convoy route that would require the dynamic networking of the convoy to different sensors. Or perhaps it would simply require the use of sensors in different capacities in different situations. For example, the ScanEagle UAV could be used in concert with Shotspotter and CoT to locate the enemy, then to investigate the convoy route ahead and then finally to help the convoy commander maintain his SA during combat operations. The ability to adapt to situations is what needs to be tested with edge experiments.

C. POWER TO THE EDGE COMMAND AND CONTROL IMPLICATIONS

1. Technology

Transforming the military into an edge organization will require major changes to the current military structure, culture and TTPs (Techniques, Tactics, and Procedures). One of the biggest changes we can expect in the future is vast improvements in technology as a whole. Optimistically, by 2050 bandwidth, connectivity, and computing power all will be problems of the past. As such,

³³ Alberts and Hayes, 218.

edge organizations can not effectively function with present day technology. Shared situational awareness demands nearly unlimited bandwidth. Considering how quickly bandwidth technology has been progressing, bandwidth constraints should be all but eliminated by 2050. Computing power should not be an issue, again, because of the rapid developments in computing speeds. Connectivity, however, may still be a problem. Physical limitations of the frequency spectrum will eventually stop connections from working. As technology races ahead, certain physical restraints will still remain. For instance, one of the Marines participating in the EA-I experiment pointed out that none of these technologies would work in a bunker, or beneath ground because of their wireless nature. Situations absent from a commander's omnipresent orders are precisely where an empowered edge would be necessary.

2. HSI (Human System Interface)

Systems will have to improve their human interface. If a specialist is necessary to successfully conjure information from the GIG, then the system is not good enough. Our forces need throngs of battlefield sensors to exceed the limits of human observation, not to overwork an already burdened cognitive process. This function is still performed by an omniscient battlefield commander. Nevertheless, as seen in EA-II, a 3 or 4 minute turnaround on a SALUTE report from higher-up is too slow. Communications were performed through typed chat during EA-II. This system worked fairly well in a controlled environment, but will likely fail in the chaos of battle. HSI development will need to evolve to let command come from a medium that is less intensive and laborious.

3. Commanders Still in Command

War is an amorphous process that demands expediency. Today's wars are fought with increasing speed, and the wars of our future are likely to follow suit. In the Information Age, speed will be the most critical element on the battlefield, not force size. Current Command and Control doctrine is changing to meet these needs, but will eventually peak under a hierarchical control structure.

Power to the Edge may not, specifically, be the answer to fighting wars in the Information Age, but ideas about quickening the pace of our situational awareness are vital. The OODA loop will always be a part of the battlefield as long as people are involved. If one was to look at the decision-making process like an electrical circuit, the difference between an edge organization and a hierarchy would be like the difference between a set of resistors in parallel versus a set of resistors in series, respectively. If situational awareness and information are ubiquitous, however, then there is no reason why commanders and edge actors can't arrive at the same conclusion at the same time.

While *Power to the Edge* promotes the empowerment of edge actors, it does not negate the importance command and control will play in the success of our forces in the Information Age battlefield. In the same way Special Forces (SF) are empowered through commander's intent, edge organizations become empowered too. SF still follow orders, but are able to act quickly and decisively in changing environments due to their ability to self-synchronize. Ultimately, our conventional forces will need

to begin resembling our Special Forces if they are to adapt at the speeds necessary to win tomorrow's wars. Conversely, SF operations generally have a narrow focus and small unit sizes, virtues that traditional forces may never have. The genuine challenge facing our future forces is how to act with the speed and flexibility practiced by SF forces, but with a larger force, like a division. *Power to the Edge* and FCBA are merely two concepts to achieve success in the Information Age.

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